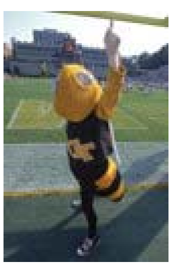
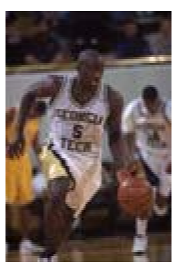
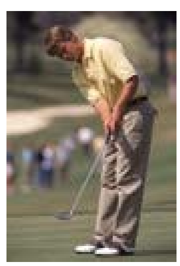
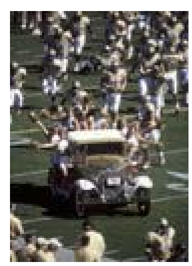
Georgia Institute of Technology









LOGANEnergy Corp.

Initial Report, CERL FY'02 Georgia Tech ROTC Demonstration Program

Georgia Tech ROTC PEM Project

Atlanta, Georgia

February 4, 2004

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Introduction

Fuel Cells convert the chemical energy of a fuel into useable electric and thermal energy without an intermediate combustion or mechanical process. In that respect, they are similar to batteries. However, unlike batteries, fuel cells oxidize externally supplied fuel and therefore do not need recharging. Ever since National Aeronautics and Space Administration (NASA) adopted fuel cell power for the Apollo Space program, American industry has been fascinated by the prospects for their use on earth as well.

When integrated with a fuel processor and a solid-state power conditioner, the fuel cell power system becomes one that produces clean, quiet and reliable electric power and heat. Several manufacturers are currently hard at work to translate the basic technology into consumer products. As advances in PEM technology and mass production converge to introduce competitively costs systems into the marketplace, many are betting that small-scale fuel cell generators will soon be ready to tackle thousands of residential and small-scale commercial power applications. These new appliances will be packaged energy systems providing both heat and electricity that will be able to operate with or without the local utility grid.

Until recently, however, the promise of fuel cell technology has been slow to advance beyond a narrow beachhead commonly referred to as the "early adopter" marketplace. Broader market appeal has been constrained by fits, false starts and premature expectations raised by eager manufacturers; but also high prices, skepticism, and not a little resistance by parochial interests have all restricted the opportunity. Notwithstanding, during the decade of the 1990s, the UTC PC25C Fuel Cell program, assisted by a significant DOD investment, gradually established a solid record of achievement and customer satisfaction at numerous US locations and around the world. Installations sites included military hospitals, commercial buildings, banks, food processing facilities, data processing centers, police stations, and airports.

While many of these "early adopters" hosted pure technology demonstration projects, the industry gained valuable experience and knowledge because of them. More recently, however, customers have warmed to the proposition that fuel cells have real performance advantages in various combined heat and critical power applications (CHP). Perhaps their attitudes and business practices may be adjusting to accommodate an uncertain energy landscape. Clearly, many energy providers are scrambling to maintain their market base, others are floundering, and still others are stalking new opportunity. Nevertheless, they are all discovering that informed consumers have gained new leverage through the power of choice. Increasingly, newspaper articles, periodicals and other media outlets are scoring direct hits with stories about fuel cells. Policy makers are out front raising expectations of a cleaner, highly efficient fuel cell/hydrogen based economy of the future. The signals are clear. Initiative and momentum are driving a rapidly maturing fuel cell industry.

Certainly one reason is because fuel cell technology represents, perhaps, the most exciting and innovative development in the energy industry today. In some ways the technology is maturing more rapidly and markets are developing more quickly than the supporting infrastructure, codes and standards are able to accommodate. However, as technology demonstrations increasingly give way to CHP fuel cell installations that provide practical solutions to demanding consumer requirements, such roadblocks should get resolved as consumer and utility interests find common ground. For example, in most applications, large-scale fuel cell installations may off-load significant power resources during critical grid demand intervals, serving utility interests, while providing "hot" back-up for mission essential loads in commercial and even residential applications. Additionally, they may also provide BTUs for heating and cooling loads-demonstrating the dual benefits of enhancing grid stability and promoting energy conservation.

At the small scale and residential end of the fuel cell spectrum, the opportunity is just as promising for the rapid expansion of distributed power generation. Conceivably, thousands of 3kW to 5kW CHP fuel cells in homes and small businesses across the country could within several years displace hundreds of MWhs of electricity and millions of BTUs with clean, efficient and reliable energy service. If this occurs, it could have a dramatic impact on both the energy industry, and on the nation's economy and security. Consumers, not utilities, could begin displacing environmentally disruptive generation methods, thereby forcing changes in the industry. As providers of grid resources, they may one day collectively enhance grid stability in many areas, boosting efficiency and conservation norms, and having a decided impact on the evolution of national energy policy.

Against this backdrop, the US Army Corps of Engineers Construction Engineering Research Lab (CERL) has contracted with LOGANEnergy through its FY'02 PEM Demonstration Program to engage a progressive fuel cell energy strategy to inform future DOD policy and planning. Broadly speaking, this engagement directs LOGAN to purchase and install residential and small-scale fuel cell power plants, and then test and evaluate their performance in widespread applications at selected military installations. Three events make this program very timely. They are (a) the complexities and perplexities of utility deregulation juxtaposed with, (b) base utility privatization programs, and (c) the nascent interest in distributed generation / CHP technologies that promise more efficient utilization of resources.

If the fuel cell industry appeared very much ahead of a languid power market in the recent past, today those markets are in comparative turmoil. Prices and availability, in some cases, are volatile and beyond the comprehension of energy managers and consumers alike. Consumers who are seeking innovative and efficient energy solutions for greater comfort, convenience and reliability are adding a new urgency. If the fuel cell industry can capitalize on these conditions, it will have a rich market opportunity, but it will have to deliver energy services and benefits that are immediate, site specific, cost effective, energy efficient, and certifiably green!

In order to test and evaluate the state of PEM fuel cell technology against these challenges, LOGANEnergy Corporation will demonstrate over the course of a year a PEM small-scale fuel cell at the Georgia TECH ROTC location in Atlanta, GA. The project will be guided by an operations plan that will direct the installation, testing, evaluation and reporting on the performance of the unit. The objectives of the plan include;

1. Evaluating installation methods in order to help standardize safe and cost effective installation practices,
2. Evaluating "out of the box" reliability and interoperability with existing facility electrical and mechanical systems / infrastructure,
3. Evaluating actual PEM operating characteristics as compared to manufacturer representations,
4. Measuring the cost of operating a PEM unit under real market conditions,
5. Measuring, collecting and analyzing operating data including, total load hours, availability, kW production, fuel consumption, water consumption, forced outages, serviceability, and manufacturer's support.
6. Introducing PEM technology, power distribution and energy efficiency to DOD and local stakeholders in the community.

The project will be led by LOGANEnergy and supported by Georgia Tech Facilities Staff, Plug Power and Energy Signature Associates.

GA Tech Air Force ROTC Building

Figure 1, Air Force ROTC Detachment 165 Headquarters

In October 2001, Sam Logan of LOGANEnergy contacted Dr. David Parekh, assistant Director of the GA Tech Research Institute, to propose partnering a DOD PEM fuel cell demonstration at the Air Force ROTC building at GA TECH. Dr Parekh resounded positively and planning began in which LOGAN would submit the site to CERL for the FY'02 Program.

In August 2003, the site was approved as an amendment to DACA42-03-C-0024, and then in early December the individuals listed on the POC form in Figure 14 below, met for the project kickoff meeting. On January 16, the unit was delivered to GA Tech in preparation for installation.

Figure 2, Rear Entrance of AF ROTC Building

Figures 1 and 2, above and at right, are photos of the GA Tech Air Force ROTC Detachment 165 headquarters building. ROTC students regularly meet at classrooms located within the facility to receive training and education in military sciences.

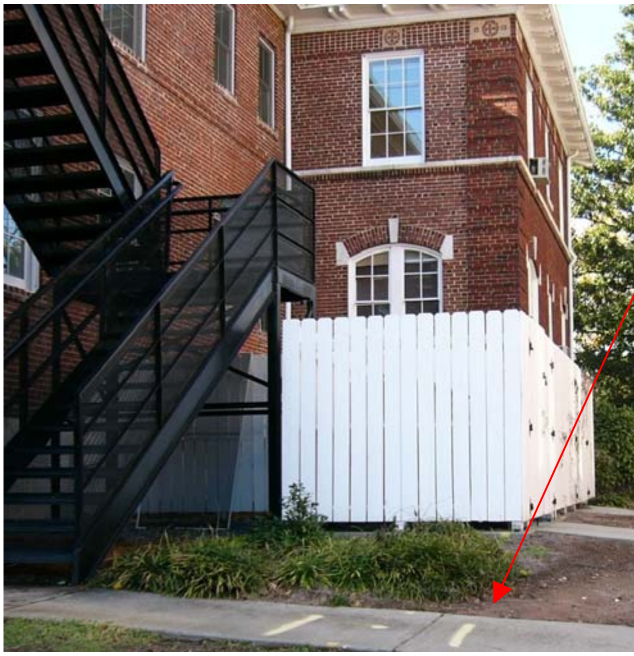


Figure 3, at left, is the location for the fuel cell pad site. Natural Gas fuel is available behind the white fence.

Figure 3, Additional View

Figure 4, at right, is a photo of the facility hot water heater that will be thermally integrated with the fuel cell.

Figure 4, Facility Hot Water Heater

Figure 5, at right, is a photo of the ROTC building electric service panel where the fuel cell grid parallel circuit will be installed. A new emergency load panel will be installed next to panel in the photo and up to 25 amps of normal building loads will be connected to it. This panel will be energized by a separate grid-independent conductor from the fuel cell as illustrated in the line diagram in Figure 8.

Figure 5, Facility Electrical Connection

Figure 6, Typical Thermal Recovery Installation

Figure 6, at left, shows a typical thermal/mechanical interface with a hot water supply. By circulating a glycol/water solution through the Heliodyne heat exchanger, waste heat from the fuel cell at the GA Tech ROTC installation will be transferred to the hot water tank.

SITE COMMUNICATIONS PACKAGE

Following is the drawing of Connected Energy equipment necessary to commission Plug Power fuel cell genset sites in order to communicate with a remote and central data center securely via the Internet. One CENTRYWCC communicates with the Plug Power controller, and another CENTRYWCC is dedicated to interface with the site meters and sensors via CENTRYPIA. The CENTRYPIA allows communication with multiple pulse or analog inputs. The VPN router at the site encrypts the traffic between the site and the data center to make a very secure connection, similar to what banks use to send financial information over the Internet. The modem is optional. If the site allows for direct network access, no modem is necessary (see cost reduction discussion following). Other modems can be used at sites where access or cost drives alternative communication strategies to DSL.

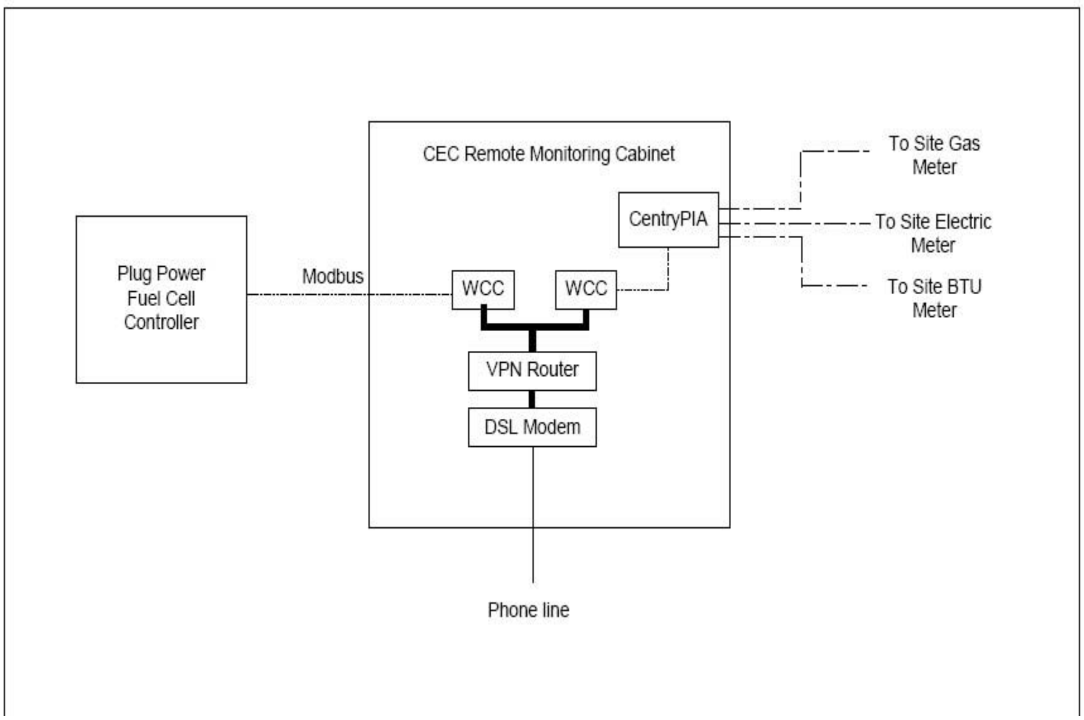


Figure 7, Communications Package

Installation Line Diagram

Georgia Tech ROTC PEM Installation Line Diagram

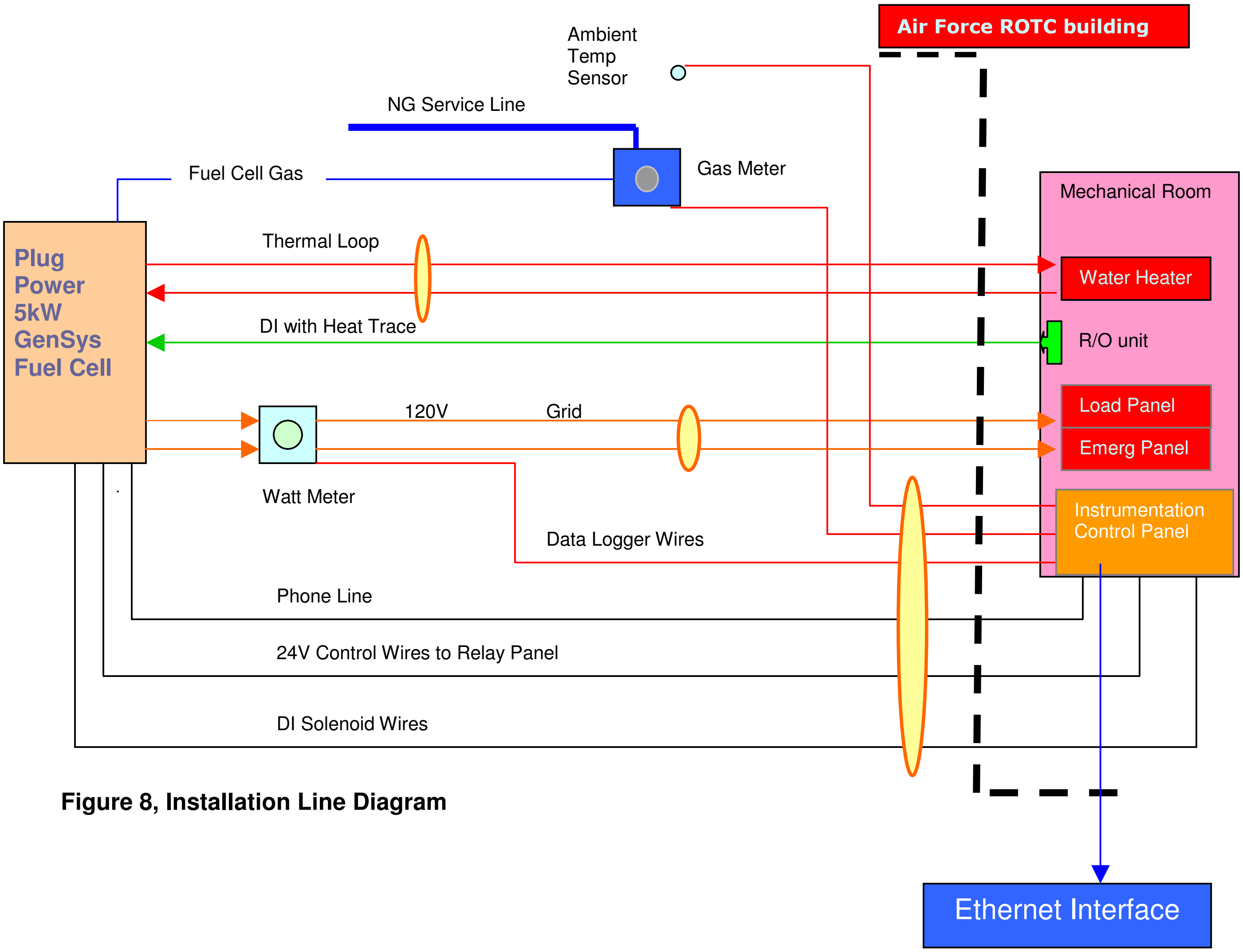
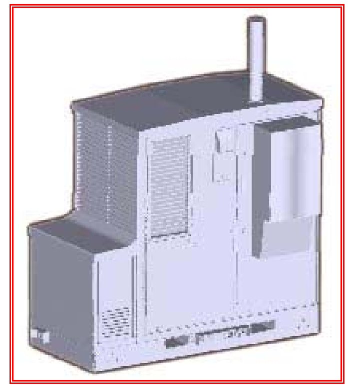


Figure 8, Installation Line Diagram

GenSys5C Product Specifications

Plug Power Fuel Cell System

The GenSys5C is a 5kWAC on-site power generation system fueled by natural gas. Designed to be connected to the existing power grid, the 5C is a clean and efficient source of power.



Specifications

Physical	Size (L X W X H):	84 1/2" X 32" X 681/4"
Performance	Power rating:	5kW continuous
	Power set points:	2.5kW, 4kW, 5kW
	Voltage:	120/240 VAC @ 60Hz
	Power Quality:	IEEE 519
	Emissions:	NO_X < 5ppm
		SO_X < 1ppm
		Noise < 70 dBa @ 1meter
Operating Conditions	Temperature:	0°F to 104°F
	Elevation:	0 to 750 feet
	Installation:	Outdoor/CHP
	Electrical Connection:	GC/GI
	Fuel:	Natural Gas
Certifications	Power Generation:	CSA International
	Power Conditioning:	UL
	Electromagnetic Compliance:	FCC Class B

Dimensions

Length	84 inches
Width	32 inches
Height	68 ¼ inches

Operating Requirements

Fuel Type	Natural Gas
Temperature	0 degrees F to 104 degrees F

Outputs

Power Output	5kW
Voltage	120/240 VAC @ 60Hz
Noise	< 70 dBA@ 1 meter

Certifications

CSA International	Fuel Cell System
UL1741	Power Conditioning Module
IEEEP1741	Grid Parallel Generation

Figure 9, Product Specifications

Installation Application

Figure 8 above, describes a one line diagram of the Georgia Tech ROTC fuel cell installation. The diagram illustrates utility and control interfaces including, gas, power, water and instrumentation devices that will be installed in the electrical and mechanical rooms of the ROTC building. Figure 9, above, lists the specifications of the Plug Power GenSys5C PEM technology demonstration fuel cell chosen for this site.

The electrical conduits between the facility load panels, Figure 6, and the fuel cell are estimated to be 100 feet. The Reverse Osmosis/DI water tubing run that provides filtered process water to the power plant will be approximately 150 feet distance, and the thermal recovery piping runs between the fuel cell and the hot water heater will also be approximately 150 feet. A Heliodyne heat exchanger will be attached to the existing hot water heater located in the mechanical room seen Figure 4 above. Fuel Cell waste heat should be adequate to meet the domestic hot water demand of the facility. Data management will be accomplished with a Connected Energy Remote Terminal Unit (RTU) Communications package as illustrated in Figure 7. The Plug Power fuel cell inverter has a power output of 110/120 VAC at 60 Hz, matching the building distribution panel in the facility electrical room with its connected loads at 110/120 VAC. The installation includes both a grid parallel and a grid independent configuration.   A two-pole wattmeter monitors both the grid parallel and grid independent conductors to record fuel cell power distribution to both the existing panel and the new emergency load panel.

LOGAN will connect the fuel cell gas piping into the existing service line adjacent to the fuel cell pad behind the white fence seen in Figure 3 above. A regulator at the fuel cell gas inlet will maintain the correct operating pressure at 14 inches water column.

A phone line connection with the fuel cell modem will provide communications with Plug Power and LOGAN customer support functions.

The installation will proceed with the utmost consideration for the health and safety of students and visitors and will be guided by an installation safety plan attached (Figure 16).

Permitting

LOGAN will cooperate with the GA Tech Facilities Management staff to insure the installation satisfies all environmental requirements. Buried utility services will be located and marked before applying for a digging permit. The site will be constructed and maintained in accordance with GA Tech health and safety guidelines. An air quality permit will not be required for this site.

Start-up and Commissioning

Prior to starting the unit the items covered in Figure 10 below, will be completed. LOGAN's fuel cell systems technician will continue to test and monitor the unit in accordance with the factory recommended procedures to insure completion of the items listed in Figure 11 below. Operations testing and tuning of the fuel cell's electrical and mechanical systems will continue to insure smooth and reliable performance. The first start is scheduled for late February 2004.

Service incidents and facility calls will be reported on the sample Service Call Report form listed below as Figure 12.

An Economic Analysis of the GA Tech AF ROTC project appears in Figure 13 below.

Installation Check List

TASK	SIGN	DATE	TIME(hrs)
Batteries Installed			
Stack Installed			
Stack Coolant Installed			
Air Purged from Stack Coolant			
Radiator Coolant Installed			
Air Purged from Radiator Coolant			
J3 Cable Installed			
J3 Cable Wiring Tested			
Inverter Power Cable Installed			
Inverter Power Polarity Correct			
RS 232 /Modem Cable Installed			
DI Solenoid Cable Installed with Diode			
Natural Gas Pipe Installed			
DI Water / Heat Trace Installed			
Drain Tubing Installed			

Figure 10, Installation Check List

Commissioning Check List

TASK	SIGN	DATE	TIME (hrs)
Controls Powered Up and Communication OK			
SARC Name Correct			
Start-Up Initiated			
Coolant Leak Checked			
Flammable Gas Leak Checked			
Data Logging to Central Computer			
System Run for 8 Hours with No Failures			

Figure 11, Commissioning Check List

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Service Call Report

SERVICE CALL REPORT

System Serial #:__________________________

SYSTEM INFORMATION

Date:______________________________

Purpose of Service Call ☐Repair ☐Maintenance ☐ECN (Check all that apply)

	Date	Time
Date/Time shutdown	____________________	____________________

MAINTENANCE / REPAIR INFORMATION

Service Tech Name: ______________________________

Travel Man-hours: ______________________________

Troubleshooting Man-hrs: ______________________________

Repair Man-hours: ______________________________

Spare Part Delay Time: ______________________________

Work Performed: ______________________________

Technician

Comments: ______________________________

FAILURE REPORT SUMMARY

Date	Description of Problem	Rpt #	Initials

Figure 12, Service Call Report

LOGANEnergy Corp.

FY' 02 RESSDEM
GA Tech Proforma Fuel Cell Economic Analysis

Estimated Project Utility Rates	
1) Water (per 1,000 gallons)	$1.69
2) Electricity (per KWH)	$0.0345
3) Natural gas (per MCF)	$5.25

Estimated First Cost	
Plug Power 5 kW SU-1	*$65,000*
Shipping	*$1,800*
Installation electrical	*$4,250*
Installation mechanical	*$3,200*
Watt Meter, Instrumentation, Communication	*$15,500*
Site Prep, labor materials	*$925*
Technical Supervision	*$8,500*
Total	***$99,175***

Assume Five Year Simple Payback **$19,835**

Forcast Operating Expenses	Volume	$/Hr	$/ Yr
Natural Gas			
Mcf/hr @ 2.5kW	*0.032838*	*$0.17*	*$1,359*
Water			
Gals/Yr	*4918*		*$8.31*

Add Total Annual Operating Costs	**$1,368**
Total Annual Costs (Ammortization + Expenses)	**$21,203**

Economic Summary		
Forcast Annual kWH	*19710*	
Annual Cost of Operating Power Plant	*$0.0694*	kWH
Credit Annual Thermal Recovery	*-0.016489*	kWH
Project Net Operating Cost	*$0.0529*	kWH
Ammount Available for Financing	*($0.0184)*	kWH
Add 5 Yr Ammortization Cost / kWH	*$1.0063*	kWH

Current Demo Program Cost Assuming 5 Yr Simple Payback **$1.0757 kWH**

***NOTE**Does not include allowance for cell stack life cycle costs or service over 5 year economic senario*

Figure 13, Economic Analysis

Project POC List

GA TECH PEM Fuel Cell Demonstration Program

Host Site Program Manager
Colonel Terry McCarthy
(404) 894 - 4175
terrance.mccarthy@rotc.gatech.edu
Host Site Project Manager
David Parekh
(404) 894 - 3400
david.parekh@gtri.gatech.edu
Host Site Assistant Project Manager
Comas Haynes
(770) 528-7578
comas.haynes@gtri.gatech.edu
Host Site Project Engineer
David Chandler
(404) 894-3624
david.chandler@facilities.gatech.edu
Host Site Facilities Manager
Don Alexander
(404) 894-4235
don.alexander@facilities.gatech.edu
LOGANEnergy Project Developer
Sam Logan
(770) 650-6388 office
(770) 330-6600 cell
samlogan@loganenergy.com
LOGANEnergy Installation Manager
Mike Harvell
(770) 330-6400
mikeharvell@loganenergy.com
DoD Fuel Cell Program Manager
Mike Binder
(217) 840-2323
m-binder@cecer.army.mil
Plug Power Project Engineer
Brian Davenport
(518) 727-4553
brian_davenport@plugpower.com

Figure 14, Project POCs

Site Location:

Air Force ROTC Detachment 165, 685 Cherry St NW, Atlanta, GA

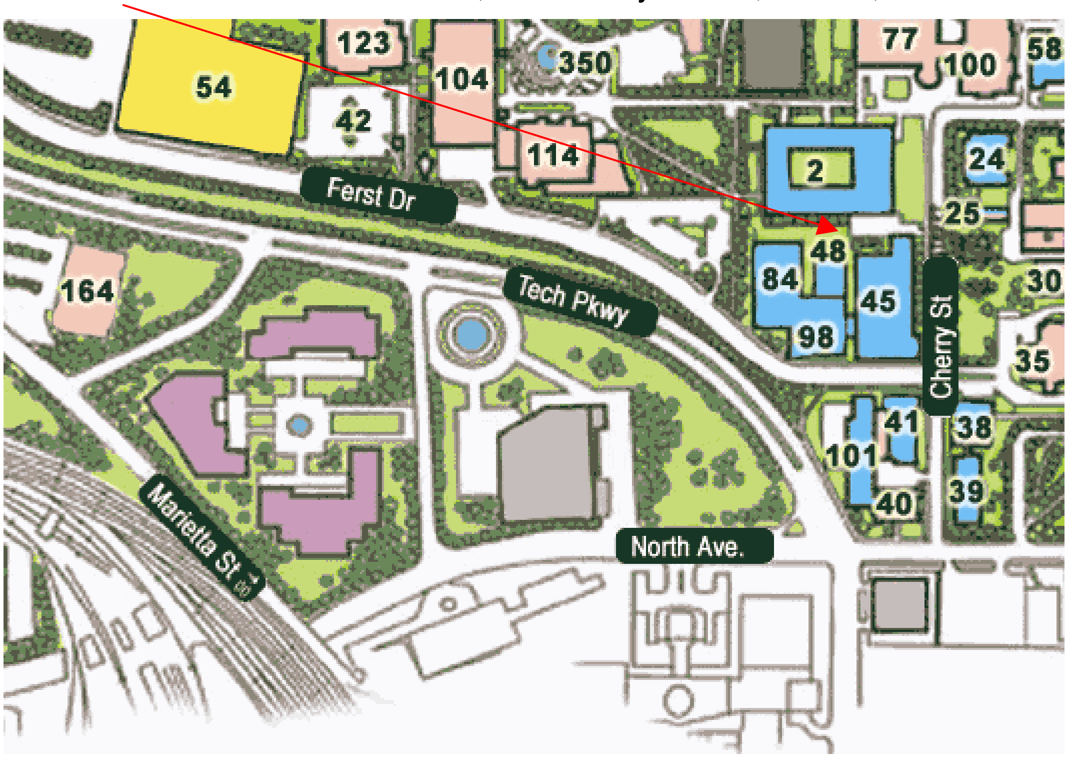

Figure 15, Location

Installation Safety Plan

Project Personnel		
Project Manager	**LOGAN Project Manager/Representative**	**Emergency Medical Response**
David Chandler (404) 894-3624	**Name** Mike Harvell (803) 635-5496	**Grady Memorial Medical Center**
Project Contractors	**Other Personnel**	**Specialized Equipment for Tasks**
Shiflett Electric 404-753-6104 Milo Plumbing 803-732-0177	Col Harry McCarthy 678-283-6608	Fork Truck, Thermal Welder, Power Drill, Various Power Tools

Installation /Construction		
Tasks	**Perils**	**Mitigation**
1. Hand Trench 50 feet 1/2" NG Line	Cut/damage other buried utilities, conduit, lines	Locate and Mark buried utilities before trenching.
2. Hand trench 150" water line.	Cut/damage other buried utilities, conduit, lines	Practice correct tie-in techniques, use trained personnel.
3. Offload 2,200 PEM Fuel Cell	Damage Equipment, harm/injure personnel.	Use trained equipment operators with trained observers.
4. Electrical/Mechanical Installation	Electric Shock to personnel. Injury or harm working with power tools.	Use "LOTO" procedures; avoid working "HOT" circuits Use trained personnel on all installation tasks.
5. Initial Start of Equipment	Damage Equipment, harm/injure personnel.	Use factory trained personnel, follow procedures.
6. Maintain General Site Conditions	Unkempt Site...Danger to residents and visitors.	Remove loose materials, tools, police site at end of each day. Place yellow caution ribbon around installation/work areas.
7. Maintain Safe Work Environment	Injury, loss of equipment, materials, customer dissatisfaction, loss of time and money.	Manager's Representative to encourage safe practices by all contractor personnel; critique unsafe practices; and lead by example.
8. Personnel Safety	Head, hand and foot injury.	Construction/installation crews shall wear appropriate personal protective gear while performing job site tasks.

Figure 16, Safety Plan